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AN INTENSIVE APPROACH TO THE STUDY OF MATERIALS DETERIORATION IN THE TROPICS

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AN INTENSIVE APPROACH TO THE STUDY OF MATERIALS DETERIORATION IN THE TROPICS (U)

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INTRODUCTION The purpose of this paper is to report an experiment in tropic material degradation being conducted by the US Army Tropic Test Center. The experiment differs from many other studies of the same phenomenon by emphasizing a higher data rate, expanded geographic coverage and extensive laboratory analyses. This paper will cover early results only, representing a fraction of the data that will be available at the conclusion of the study.

The climate of the humid tropics affects military materiel in two main ways. Military standards and specifications generally deal with the direct influence. For instance, they deal with the heating and cooling of materiel through ambient temperature, sunshine and humidity cycles.

There are, however, very effective ways that climate can affect materiel indirectly. Because there is no cold weather in the humid tropics, macro- and microorganisms exist that could not survive in a climate that has a winter or which has a desert-dry season. The metabolic products of tropical organisms can affect, and in extreme cases destroy, military equipment even when the climatic conditions stay well within the extremes set as tolerance limits of direct climatic effects.

Since the discrepancy between climatic data and climatic effects is well known to everybody who ever lived in the tropics, experiments were begun many years ago to assess the effects of the humid tropics.

Materials (spelled with an "a") and materiel (spelled with an "e") were exposed and the course of deterioration was checked from time to time, mainly through visual inspection of material or a go-no go basis of materiel.

Begin 201

METHOD Our present project is designed another way. The materials are not placed just anywhere, but on 16 different, carefully selected sites representing a range of vegetation and terrain associations commonly found in the tropics. There are only six materials of differing chemical compositions that are exposed at each of the sites in exactly the same way, in blocks of twelve specimens each. In addition, control racks are kept in an un-lighted air-conditioned room of our laboratory.

Figure 1 shows one of the open sites, Figure 2, one of the sheds. The materials on the racks are steel (5 mil thick), plasticized polyvinyl chloride (PVC), butyl rubber, natural rubber, nylon, and cotton. At intervals ranging from one week to one month, one strip of each material is collected from each site and submitted to a series of physical and chemical tests in our laboratory. In the course of time a deterioration history evolves for each material at each site.

Every three months new samples are fastened on additional racks in order to cover the following seasonal periods: early wet, late wet, early dry, late dry.

Figure 3 shows the locations of the sites. There are two coastal sites (Flamenco Island and Galeta Point) where the samples are exposed on open racks to a salt laden atmosphere and much sunshine. Six additional sites are open and uncovered, but not coastal (Gun Hill, Chiva Chiva, Gamboa, Ft. Gulick, Coco Solo, Ft. Sherman). Four sites are in deep evergreen or semievergreen forest where humidity is abundant and sunshine scarce or non-existent (Pacific Forest, Gamboa, Coco Solo, Ft. Sherman). Three sites are open sheds where the materials are protected against rain and most radiation, but where the ambient air can circulate freely (Chiva Chiva, Ft. Gulick, Coco Solo). Finally, one site was erected in the Mangrove Swamp (Coco Solo).

At all of the sites meteorological instruments were installed. It soon became obvious that the two parameters that are predominantly emphasized in regulations, standards, and test criteria, namely ambient temperature and relative humidity, are of least importance, and the hygrothermographs were consequently removed from several sites.

Figure 4 shows the mean maximum temperature and the temperature range measured in November 1971 at all sites. This month displayed a wide variety of weather patterns so that it can be taken as representative for the climate in general. A presentation of relative humidity would show a similar clustering of site names. I ask you to keep in mind the narrow range of temperature shown here when you next observe the enormous differences of deterioration at these same sites.

ANALYSIS The following kinds of documentation are obtained in the laboratory: color photographs, each provided with a calibrated color standard; reflectivity at different wavelengths from the upper side as well as from the underside; growth and kind of fungi when parts of the samples are placed on agar; breaking strength and elongation; microscopic inspection of cracks, their number as well as their shape, transparency and reflectivity where applicable.

RESULTS Time permits presentation of only one measurement--smoothed time curves of tensile strength.

Some of the early results were startling and unexpected. The first family of samples was placed on the racks on 7 April 1971. One day later, inspection revealed that the steel samples under the mangrove trees were already 70% covered with rust while the steel samples at all other sites still looked new.

Figure 5 shows the deterioration of steel during the first exposure period. The ordinate indicates breaking force; the abscissa duration of exposure in days. The mangrove curve reaches zero at approximately 55 days. Only seven samples had been collected up to this time, the remaining five samples later fell in pieces from the rack.

Contrasting to this, the perenially wet forest caused a reduction in strength that was only slightly more than that in the shed, and slightly less than over grass.

The coast with its high saltfall also produced rapid destruction of steel.

It can be seen on Figure 6 that also natural rubber (latex) shows very definite deterioration, but the influences of the different subenvironments do not parallel those of steel. (In this and the following two slides, the four forest sites and the three sheds are averaged).

The deterioration of latex is lowest in the forest, particularly during the early wet season (line F I). In the sheds, where the latex is not protected by wetness, debris, and jungle canopy from higher light levels, deterioration is much greater than in the forest.

The open sites, whether at the coast or inland, reduce the breaking strength of latex in only three weeks to less than a tenth of its original value.

Mangrove again induced greater deterioration than jungle, which may be due to greater light penetration, higher salinity, different air chemistry or some combination of these.

In contrast to natural rubber, artificial rubber (butyl) did not show any statistically significant differences among sites, or any significant deterioration in the course of 231 days exposure time. The same was true for polyvinyl chloride (PVC). This holds, of course, for physical measurements. The chemical analyses, now underway, may tell a different story.

Nylon is another material that was exposed. Nylon has two significant tensile strengths; one of them is the breaking strength, the other is the strength at which the molecules rearrange themselves.

In Figure 7 the ordinate denotes stretching force; the abscissa shows elongation. The bold curve is identical in both parts of the diagram, and refers to unexposed nylon. It can be seen that the unexposed nylon has a continuation of the elongation with reduction of stretching force once a rearrangement of the molecules has begun. After this is completed, further elongation is attained by increasing stretching force until the nylon breaks.

The curves that refer to conditions in the forest show that the nylon is stronger after 2 months of exposure than it was before; but after 8 months it is slightly weaker.

After two months exposure nylon in the shed and in the mangrove swamp is as strong as it was originally, but after 8 months the breaking strength is greatly reduced.

Nylon rapidly deteriorates in the open, and although it withstands a slightly larger force than originally needed to align the molecules, no such alignment occurs after two months. The breaking force becomes less and less with increasing exposure time; it is in the open only 35% of what it is in the forest after 8 months of exposure.

The last material to mention is cotton (Figures 8 and 9). It was severely attacked by light as well as by fungi; yet, in the first weeks of exposure it became stronger at those places where it could soak up moisture. Cotton is the only one of the six materials that suffered more in the forest than in any other kind of subenvironment. Microbial attack was the predominant influence in this process.

CONCLUSION Time did not permit discussion of other properties than tensile strength, nor of inhomogeneities in the data. The following conclusions are based on the entirety of analyzed measurements available at the time, and go beyond a mere summary of the data discussed in the present paper.

Within a tropical area where temperature and humidity vary only little, material deterioration rates vary a great deal.

Material and surveillance test sites cannot be characterized by an overall severity index. Severity of deterioration is material-specific as well as site-specific.

It seems obvious to those of us in the material test and evaluation work that air chemistry, particulate deposits, and microbial ecology represent the basis of cause and effect relationships. These factors depend on temperature and humidity (commonly recorded during tests) only because the lack of drastic changes provides the basis for the ecological effects. In future test programs, we will definitely need to reappraise the relative value of gross meteorological measures and the forementioned microeffects in explaining tropical degradation. Man-made modifications of the environment such as clearing the ground from forest, or erection of sheds, modify atmospheric constituents and further allow different amount of solar radiations to infringe on the test items. Aside from the heating effect the radiation influences the chemical structure of the materials through its content of ultraviolet light, and, perhaps more important, it regulates wetting and drying of surfaces--regulating in this fashion the metabolism and the longevity of microbiological deposits as well as the supply of oxygen and water for corrosive processes.

Mangrove swamps have proven to be surprisingly corrosive to some materials and relatively protective to others. Further analysis of the ecology of this significant environment seems in order.

For most of the materials, the tropical forest, with its consistently damp atmosphere is the least deteriorative environment, whereas the open exposure, with its abundance of ultraviolet light and its daily changes between dry and wet surfaces, is generally the most deteriorating environment, especially near the coast.

Our long held hypothesis that the timing of the initial exposure will decidedly influence the rate of subsequent deterioration seems to be confirmed. In the paper it has been shown that the rate of deterioration was greater when the exposure began at the end of the dry season than when it began in the rainy season itself. We are now analyzing the late wet and early dry season data.

FIG 1

EXAMPLE OF EXPOSURE IN THE OPEN

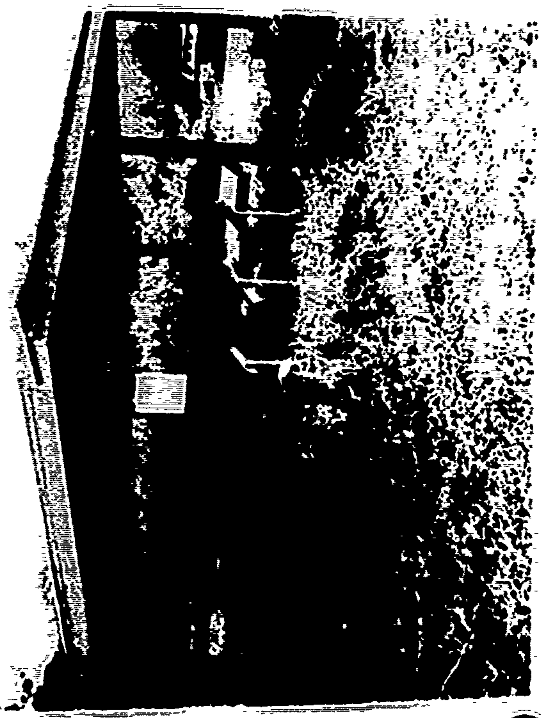

FIG 2

EXAMPLE OF EXPOSURE IN A SHED

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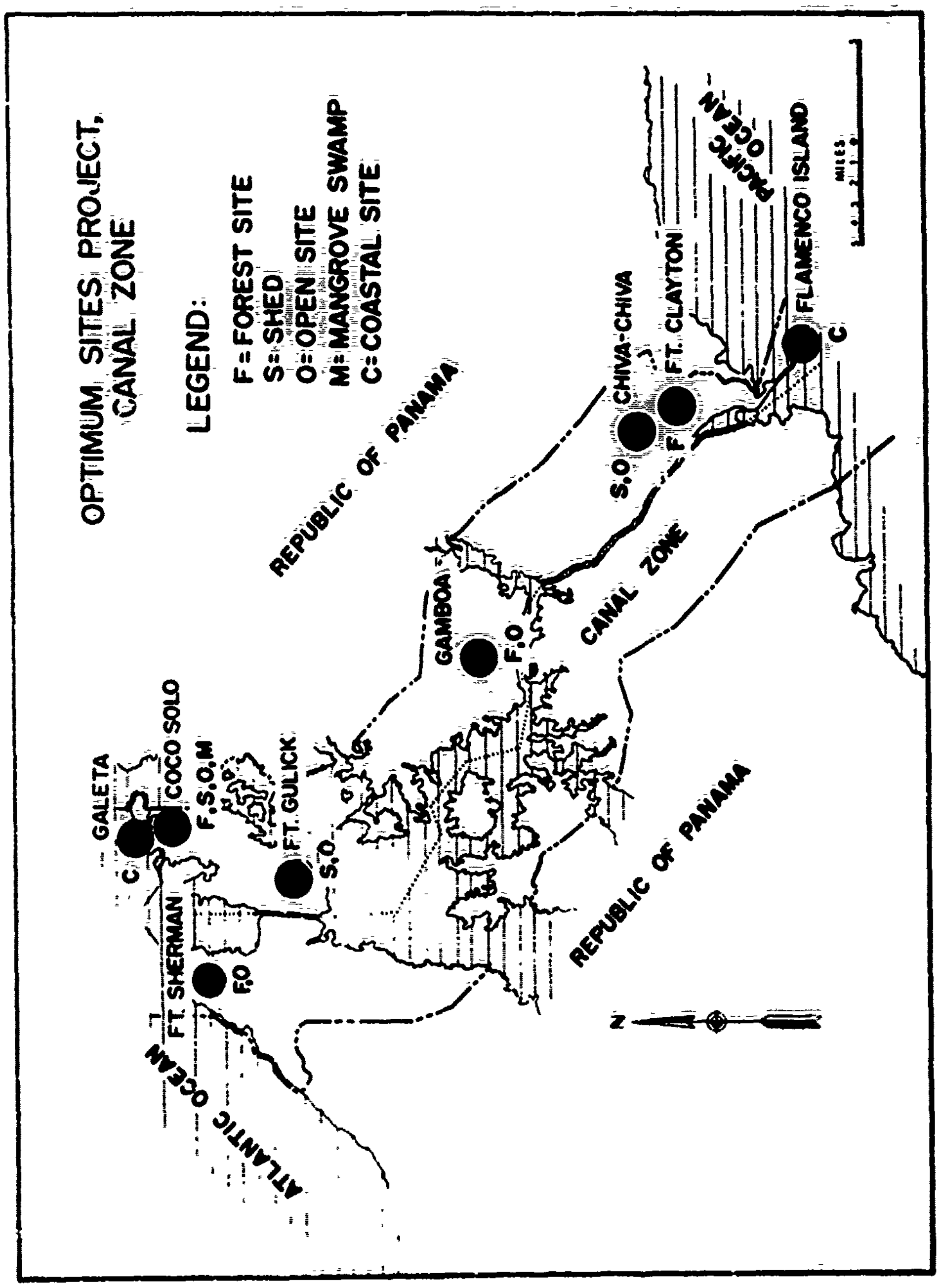
OPTIMUM SITES PROJECT,
CANAL ZONE
LEGEND:
F = FOREST SITE
S = SHED
O = OPEN SITE
M = MANGROVE SWAMP
C = COASTAL SITE
REPUBLIC OF PANAMA
CHIVA-CHIVA
S,O
FT. CLAYTON
F
FLAMENCO ISLAND
C
PACIFIC OCEAN
MILES
GAMBOA
F,O
CANAL ZONE
GALETA
C
COCO SOLO
F,S,O,M
FT. GULICK
S,O
FT. SHERMAN
F,O
ATLANTIC OCEAN
REPUBLIC OF PANAMA
N

FIG 3

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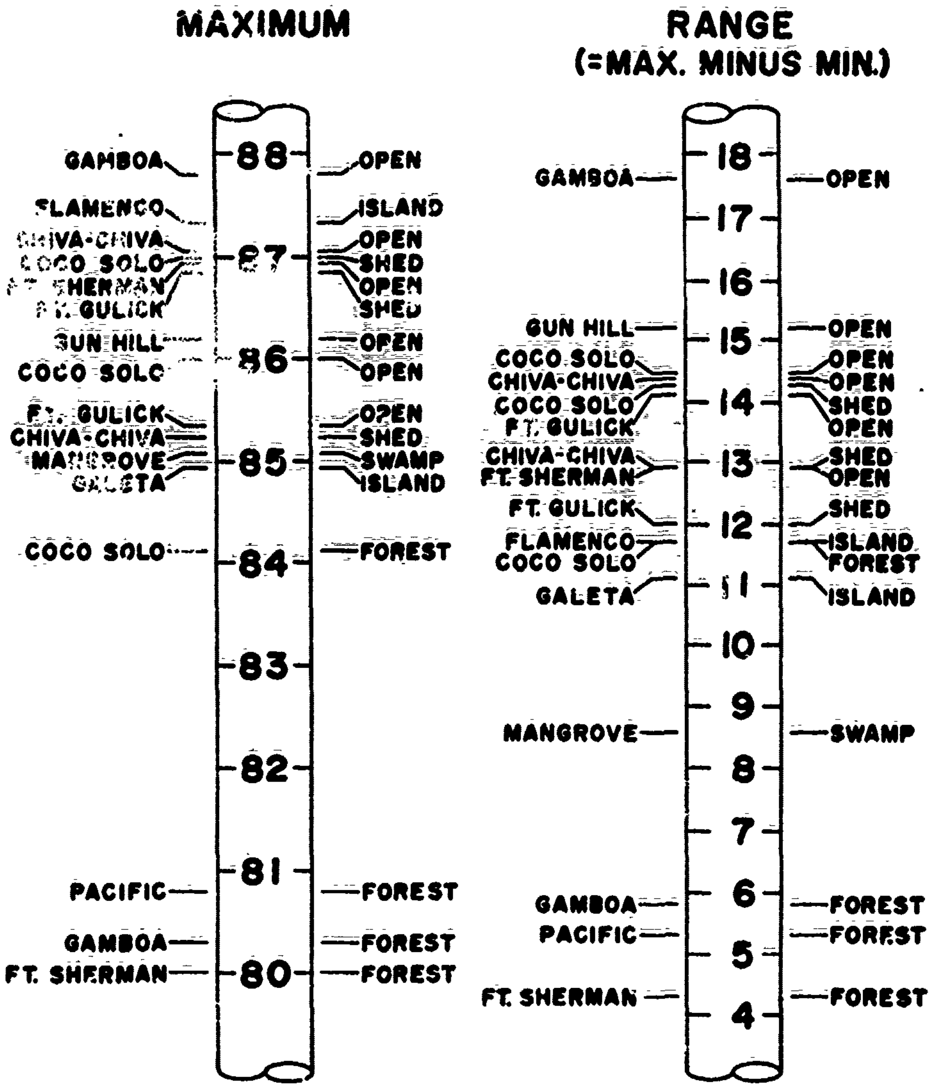

FIG. 4. MEAN TEMPERATURES
NOVEMBER 1971 (°F)

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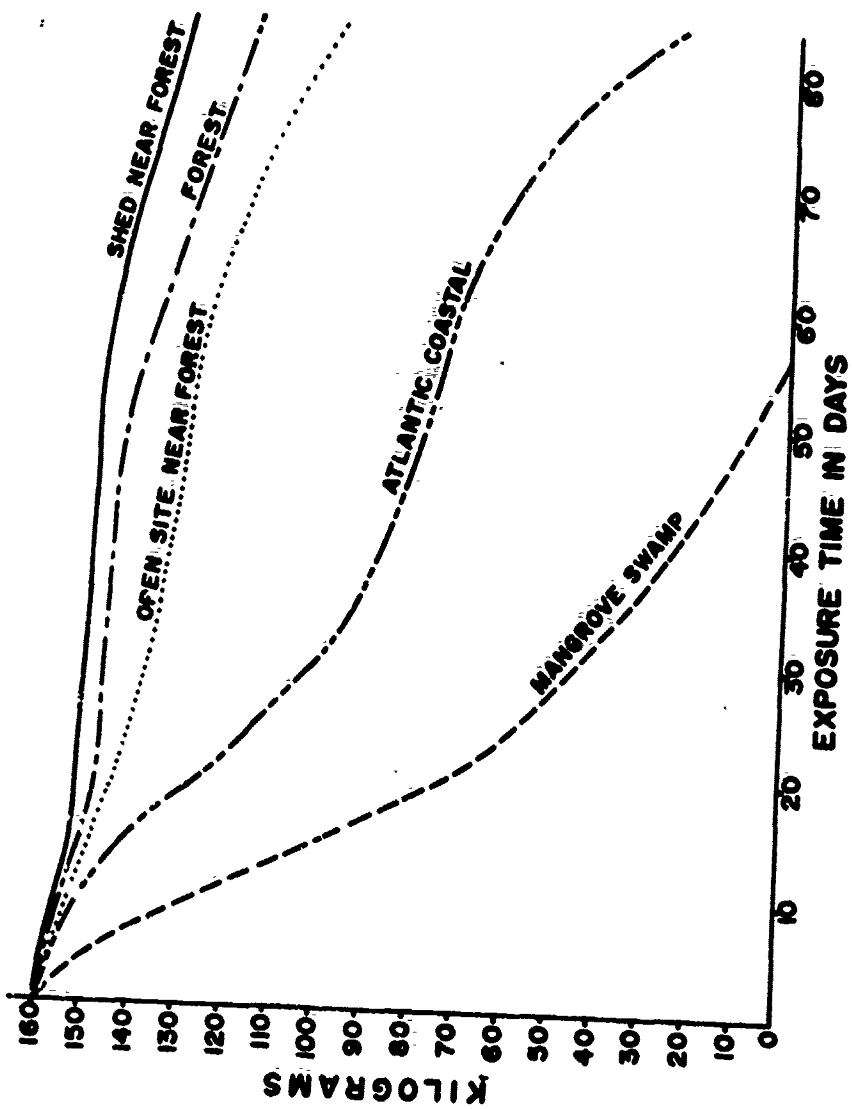

FIG. 5. TENSILE STRENGTH OF STEEL EXPOSED AT SITES IN AND NEAR COCO SOLO, C.Z.

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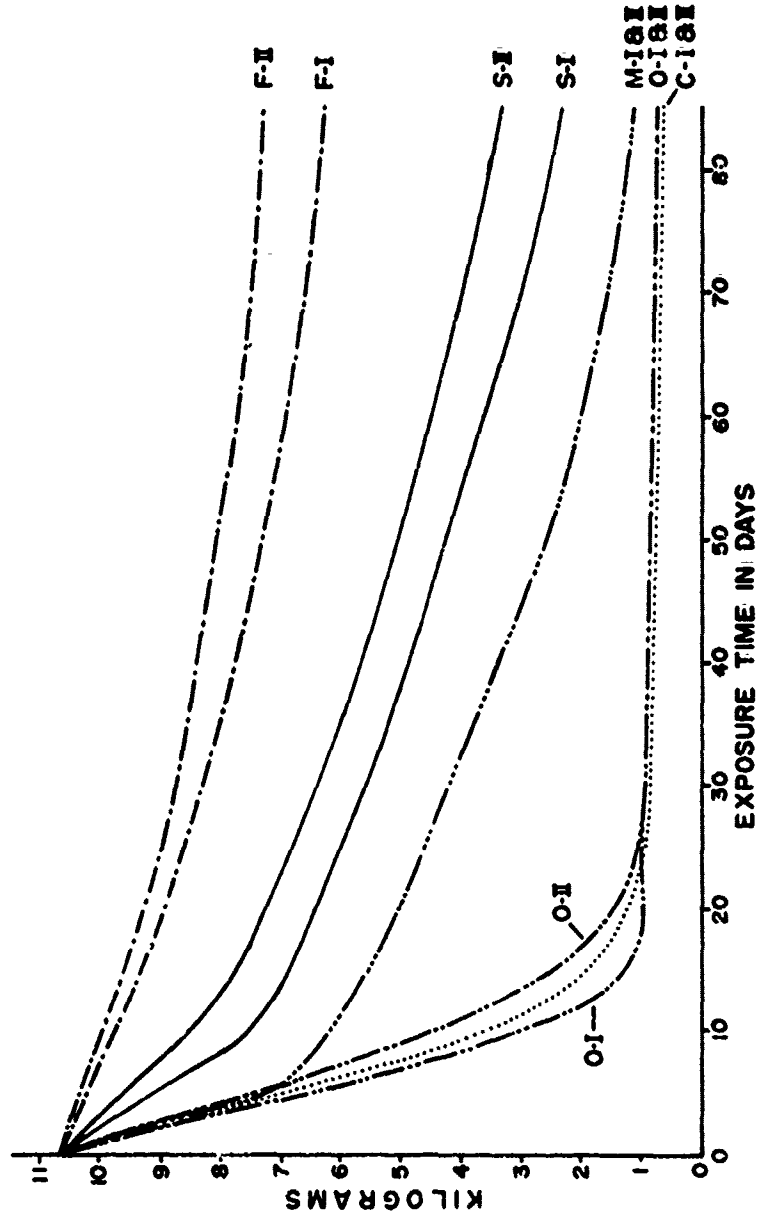

FIG. 6. TENSILE STRENGTH OF LATEX VS. EXPOSURE TIME

I= EXPOSURE BEGAN IN LATE DRY SEASON (7 APRIL 1971)
II= EXPOSURE BEGAN IN EARLY WET SEASON (6 JULY 1971)
F= AVERAGE OF SEMIEVERGREEN, TRANSITIONAL, AND HUMID EVERGREEN FORESTS
S= AVERAGE OF THREE SHEDS
O= AVERAGE OF SIX OPEN SITES
M= MANGROVE SWAMP
C= AVERAGE OF TWO COASTAL SITES

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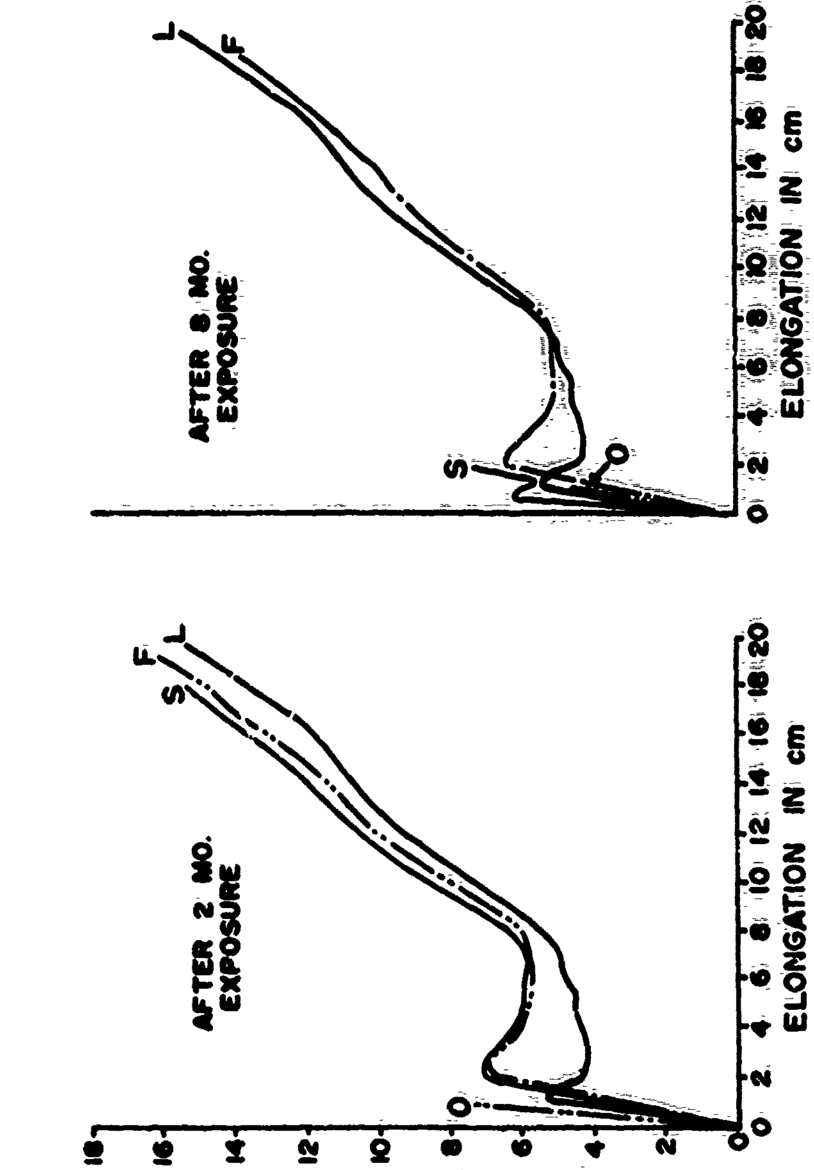

FIG. 7. TENSILE STRENGTH AND ELONGATION OF NYLON

F= AVERAGE OF SEMIEVERGREEN, TRANSITIONAL, AND HUMID EVERGREEN FORESTS
S= AVERAGE OF THREE SHEDS AND MANGROVE
O= AVERAGE OF SIX OPEN SITES
L= LABORATORY STANDARD BEFORE EXPOSURE

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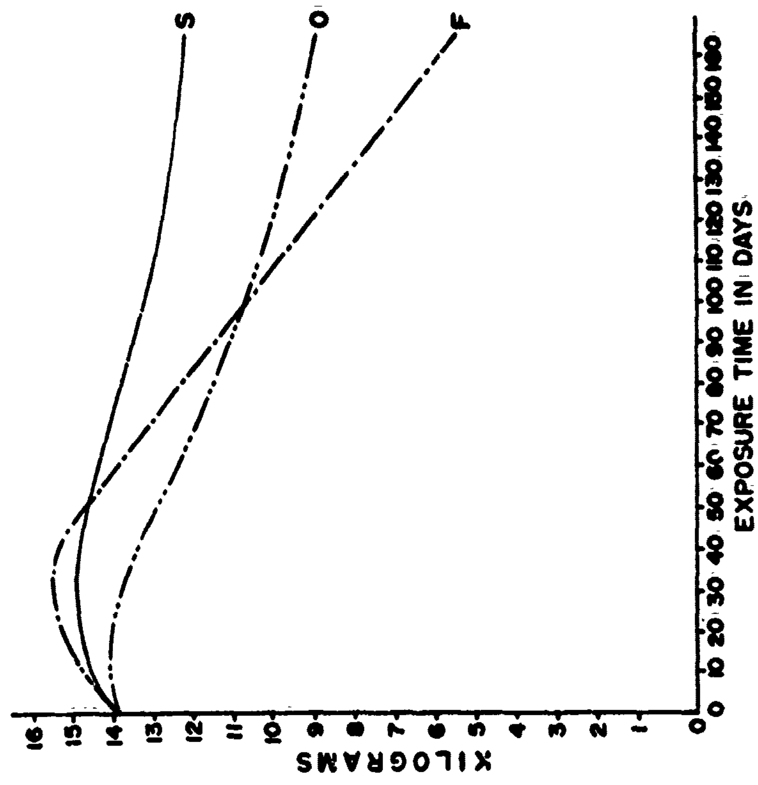

FIG. 8 TENSILE STRENGTH OF COTTON IN DIFFERENT TYPES OF CANAL ZONE ENVIRONMENTS

F: AVERAGE OF SEMIEVERGREEN, TRANSITIONAL, AND HUMID EVERGREEN FORESTS
S: AVERAGE OF THREE SHEDS
O: AVERAGE OF SIX OPEN AND TWO COASTAL SITES

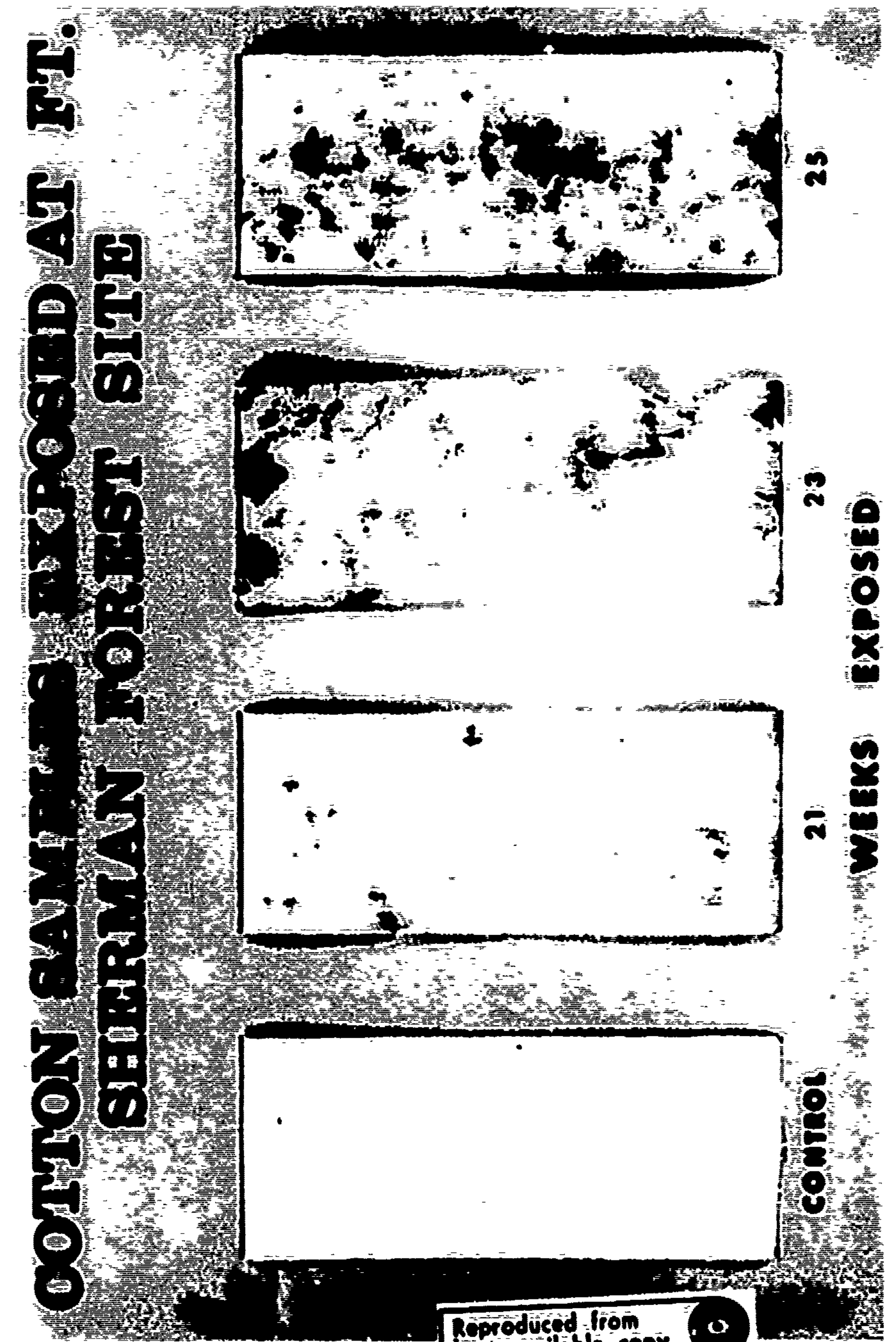
COTTON SAMPLES EXPOSED AT FT.
SHERMAN FOREST SITE
CONTROL
21
23
25
WEEKS EXPOSED

FIGURE 9